(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 141 475**
A1

(12) # EUROPEAN PATENT APPLICATION

(21) Application number: 84201595.0

(22) Date of filing: 05.11.84

(51) Int. Cl.⁴: H 01 J 35/10
F 16 C 33/10

(30) Priority: 08.11.83 NL 8303832

(43) Date of publication of application:
15.05.85 Bulletin 85/20

(84) Designated Contracting States:
CH DE FR GB LI NL

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(54) **X-ray tube comprising a helical-groove bearing.**

(57) The bearing in an X-ray tube comprising a liquid metal lubricated helical-groove bearing is provided with a push-pull bearing at one or both end faces of a bearing member. Consequently, the bearing member need not be further secured so that, notably in the case of suitable cooling of the anode disc and the bearing, extremely precise positioning of the radiation object point in the tube can be achieved.

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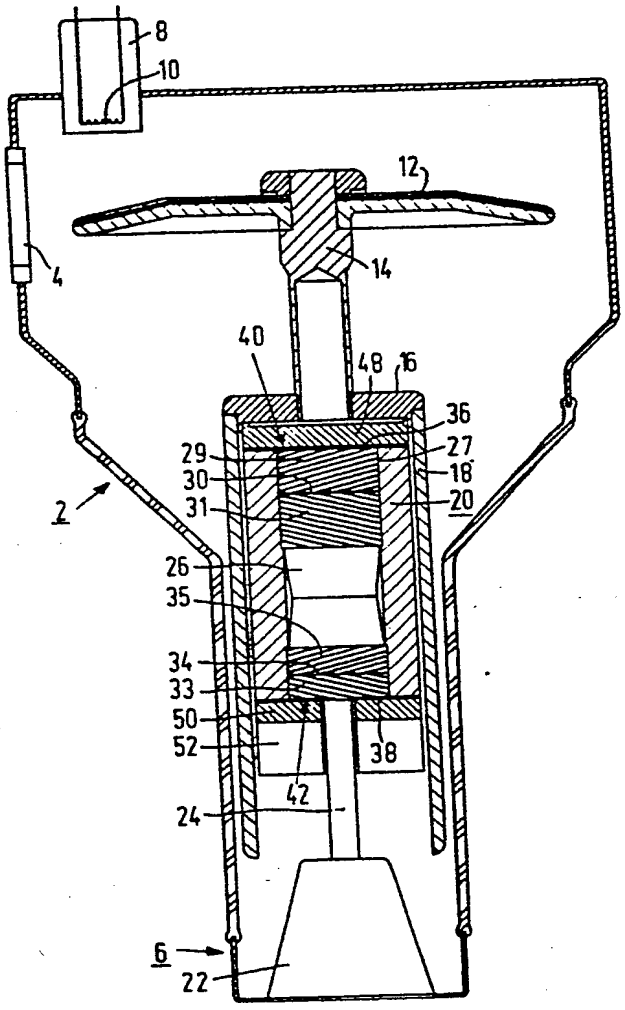
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FIG. 1

"X-ray tube comprising a helical-groove bearing."

The invention relates to an X-ray tube comprising an anode disc which is rotatably supported by a helica-groove bearing.

An X-ray tube of this kind is known from GB 2,055,432 A (PHN 9443). In an X-ray tube described therein, a rotatable anode system which comprises a rotor is journalled in a helical-groove bearing as well as in a magnetic bearing in order to achieve a reliable suspension. The latter bearing serves notably for the axial positioning of the anode system. The addition of a magnetic bearing makes an X-ray tube substantially more expensive and the comparatively strong magnetic fields of such a bearing can have a disturbing effect, for example in an X-ray image intensifier/television network or on the electron beam in the X-ray tube itself.

It is the object of the invention to avoid the use of an additional magnetic or other bearing while maintaining the attractive properties of the helical-groove bearing. To this end, an X-ray tube of the kind set forth in accordance with the invention is characterized in that an axially facing portion of the helical-groove bearing is constructed as a push-pull bearing in which a liquid metal lubricant cooperates with a pattern of helical grooves to that a comparatively strong negative pressure occurs at this area upon rotation of the bearing.

A comparatively strong negative pressure can be developed in a liquid, depending on liquid properties such as the surface energy of the liquid and on secondary conditions such as the space in which the liquid is contained and the purity of the liquid. Such a negative pressure will be lost or will not be developed when vapour bubbles can readily occur in the liquid. In order to prevent such bubbles, inclusions in the liquid and acute

wall portions of the liquid vessel must be avoided. For a suitable effect in this respect, the liquid should exhibit a comparatively strong adhesion to the wall. For a further description of these aspects reference is made to Scientific American 227, No. 6, 1972, pp. 58-71; for a more detailed description of a push-pull spiral-groove bearing as such, reference is made to Philips Technical Review Vol. 35, 1975, No. 1, pp. 11-14.

In a preferred embodiment of the invention the cooperating bearing surfaces of the bearing are made of molybdenum and/or tungsten and the metal lubricant contains Ga, for example a Ga, In, Sn alloy. The cooperating axial bearing surfaces and the helical grooves provided therein do not comprise disturbing, acute transitions and have been suitably treated for wetting by a lubricant. The Ga, In, Sn alloy has a high surface energy and an adhesion to suitable wall materials which substantially exceeds the adhesion energy and will, therefore, be suitable for achieving a comparatively strong negative pressure. Upon rotation, the bearing thus produces a self-adjusting internal bais so that the bearing need not be positioned by further bearings.

In a further preferred embodiment, surfaces of the bearing which adjoin the cooperating bearing surfaces are provided with an anti-wetting layer which consists of titanium acetylacetonate dissolved in isopropanol as described in the Patent Application PHN 10,822 filed simultaneously with the present Application.

A preferred embodiment of an X-ray tube according to the invention comprises a single helical-groove bearing with a cylindrical bearing member which is constructed as a push-pull helical groove bearing for providing support in the axial direction by providing at least one end face of the bearing member with a helical-groove pattern which produces a negative pressure. A bearing thus constructed can be provided with ducts for circulating the lubricant of the bearing. When a uni-directional bearing would cause excessive unbalance of the anode disc with respect to the

bearing, a counterweight could be mounted on a shaft portion of the anode disc which is remote from the anode disc. An X-ray tube comprising such a push-pull bearing notably comprises a ceramic support so that the anode can be maintained at any desired potential.

Some preferred embodiments in accordance with the invention will be described in detail hereinafter with reference to the drawing, in which Figure 1 shows in sectional elevation an X-ray tube which comprises a tube 2 with a radiation exit window 4, a base portion 6 and a cathode device 8 with a filament 10. An anode disc 12 is mounted on an anode shaft 14 to which a rotor 18 and a bearing sleeve 20 are secured by means of a mounting ring 16. The base portion 6 of the tube comprises, for example, a ceramic connection block 22 as described in US 4,024,424. On the connection block there is mounted a flexible, electrically conductive tube 24 on which there is mounted a cylindrical bearing member 26 which fits in the bearing sleeve 20 in both the radial and axial directions. At its cylindrical surface 27 the bearing member 26 comprises a helical-groove radial bearing which comprises a herring-bone pattern 30 of helical grooves which is formed by two groove patterns 29 and 31 which are orientated in opposite directions, potentially an intermediate piece without grooves, and a second herring-bone pattern 34 of helical grooves which is formed by two oppositely orientated helical-groove patterns 33 and 35. At its two end faces 36 and 38 the bearing member 26 comprises push-pull helical groove axial bearings 40 and 42 each comprising a pattern of helical grooves 44, for example, as shown in a front view in Figure 1a. This helical-groove pattern is again a herring-bone pattern formed by two oppositely orientated helical-groove patterns 43 and 45. A groove pattern as shown in Fig. 1a produces a pressure distribution Δp as denoted by the reference numeral 46 in Fig. 1a when provided with a suitable lubricant. This is elaborated in greater detail in the aforementioned Philips Technical Review article. Both end faces 36 and 38 of the bearing

member 26 may in principle be provided with such helical-groove bearings. Boundary surfaces between two end plates 48 and 50, with which the axial bearings 40 and 42 respectively cooperate, and the bearing sleeve 20 are provided with an anti-wetting layer in order to prevent the escape of lubricant across these surfaces. The end plates 48 and 50 may be provided with ducts through which radially accumulated lubricant can be forced to circulate in the bearing, this stimulating the lubrication. A counterweight 52 may be mounted on the bearing sleeve in order to eliminate any mass unbalance in the rotating anode system with respect to the bearing. Notably when a cooling device is used in the X-ray tube in order to limit the temperature of the anode disc and notably also of the bearing, extremely accurate positioning of a target for the electron beam and hence of an object point for an X-ray beam to be emitted can be permanently achieved. Consequently, in an X-ray apparatus comprising such an X-ray tube a suitably defined and stable beam geometry is obtained, thus improving the imaging quality of such an apparatus.

CLAIMS

1. An X-ray tube comprising an anode disc which is rotatably supported by a helical-groove bearing, characterized in that an axially facing portion of the helical-groove bearing is constructed as a push-pull bearing in which a liquid metal lubricant cooperates with a pattern of helical grooves so that a comparatively strong negative pressure occurs at this area upon rotation of the bearing.

2. An X-ray tube as claimed in Claim 1, characterized in that the bearing surfaces of the bearing are made of molybdenum and/or tungsten, the metal lubricant containing a Ga alloy.

3. An X-ray tube as claimed in Claim 2, characterized in that surfaces which adjoin the bearing surfaces are provided with a titanium acetylacetonate anti-wetting layer.

4. An X-ray tube as claimed in Claim 1, characterized in that the bearing portions are made of steel and are provided, after thermal treatment, with a metal lubricant which contains one of the metals Bi, In and Sn or a combination thereof.

5. An X-ray tube as claimed in any of the preceding Claims, characterized in that the anode disc is mounted on a rotary shaft which carries the rotor and a bearing member.

6. An X-ray tube as claimed in any of the preceding Claims, characterized in that a bearing sleeve portion is provided with ducts for circulation of the lubricant.

7. An X-ray tube as claimed in any of the preceding Claims, characterized in that the push-pull helical groove axial bearing is constructed to be double-acting, a cylindrical bearing member comprising helical-groove radial bearings being provided at each of its end faces with a pattern or helical grooves which produces a negative pres-

sure.

8. An X-ray tube as claimed in Claim 7, characterized in that the rotary shaft is provided with a counterweight at a side of the bearing which is remote from the anode disc so that the centre of gravity of the rotating system is situated at least substantially halfway between the two axial bearing portions.

9. An X-ray tube as claimed in any one of the preceding Claims, characterized in that an anode system which supports the anode disc is connected to the tube wall via an intermediate ceramic structural material.

10. An X-ray tube as claimed in any one of the preceding Claims, characterized in that for precise, stable positioning of a radiation target on the anode disc in the tube there is provided a cooling device for the anode disc and the bearing.

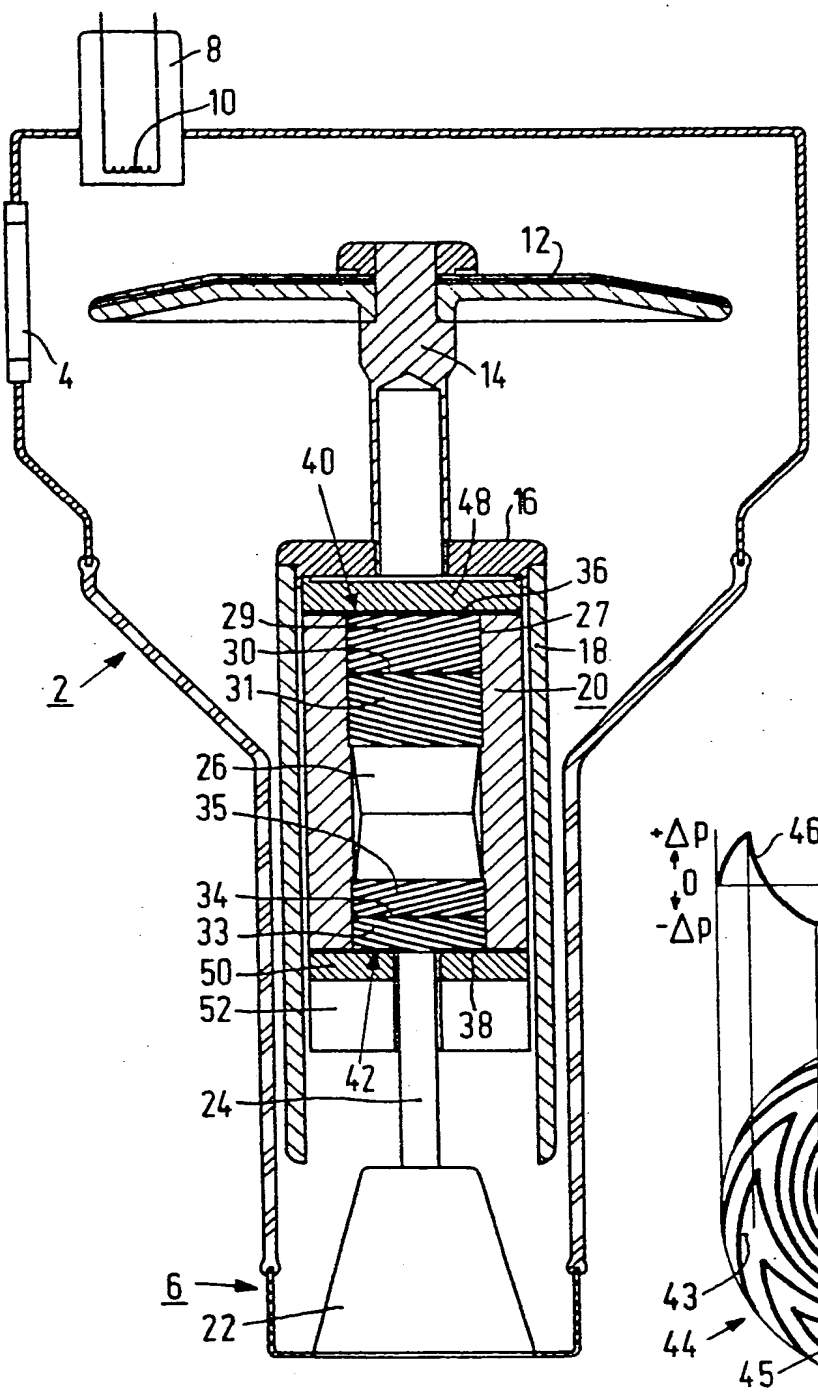
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FIG. 1

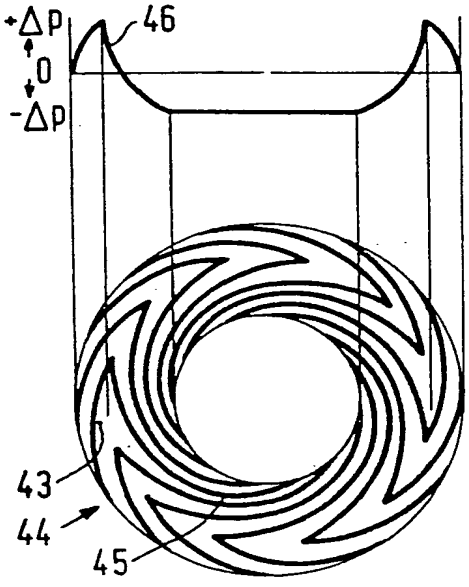
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FIG. 1a

European Patent Office

0141475

Application number

EP 84 20 1595

EUROPEAN SEARCH REPORT

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
A	US-A-4 210 371 (J. GERKEMA & E.A. MUIJDERMAN) * Column 2, line 27 - column 3, line 8; figure 1 *	1,2,5	H 01 J 35/10 F 16 C 33/10
A,D	PHILIPS TECHNICAL REVIEW, vol. 35, no. 1, 1975, pages 11-14, Eindhoven, NL; H.J.W.M. VOLMAN: "The 'push-pull' spiral-groove bearing - a thrust bearing with self-adjusting internal preloading" * Page 11, lines 1-30; figure 1c *	1,7	
A,D	GB-A-2 055 432 (N.V. PHILIPS' GLOEILAMPENFABRIEKEN) * Page 2, lines 19-99; figure 1 *	1,2,5, 9	
A	GB-A-2 038 539 (N.V. PHILIPS' GLOEILAMPENFABRIEKEN) * Page 2, lines 33-65, 93-122; figure *	1,2,5	TECHNICAL FIELDS SEARCHED (Int. Cl.4) F 16 C 33/00 H 01 J 35/00
A	CH-A- 428 332 (N.V. PHILIPS' GLOEILAMPENFABRIEKEN) * Column 1, line 18 - column 2, line 20 *	1	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	04-02-1985	HORAK G.I.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
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P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

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